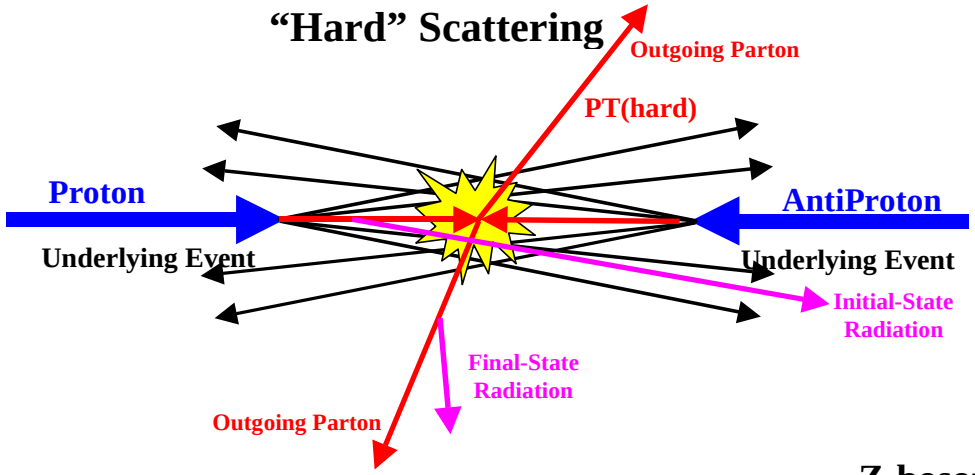
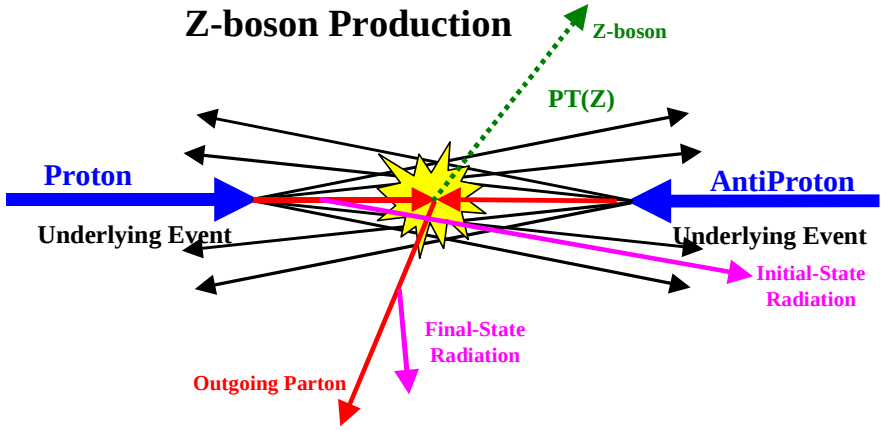
The Underlying Event: DiJet vs Z-Jet



R. Field
H. Frisch
R. Haas
D. Stuart

The "underlying event" consists of the beam-beam remnants and initial-state radiation



Comparing Data with QCD Monte-Carlo Models

Charged Particle Data

Field-Stuart Method

QCD Monte-Carlo

Look only at the charged particles measured by the CTC

Select "clean" region

- **Zero or one vertex**
- **|zc-zv| < 2 cm, |CTC d0| < 1 cm**
- **Require PT > 0.5 GeV, |η| < 1**
- **Assume a uniform track finding efficiency of 92%**
- **Errors include both statistical and correlated systematic uncertainties**

Uncorrected data

compare

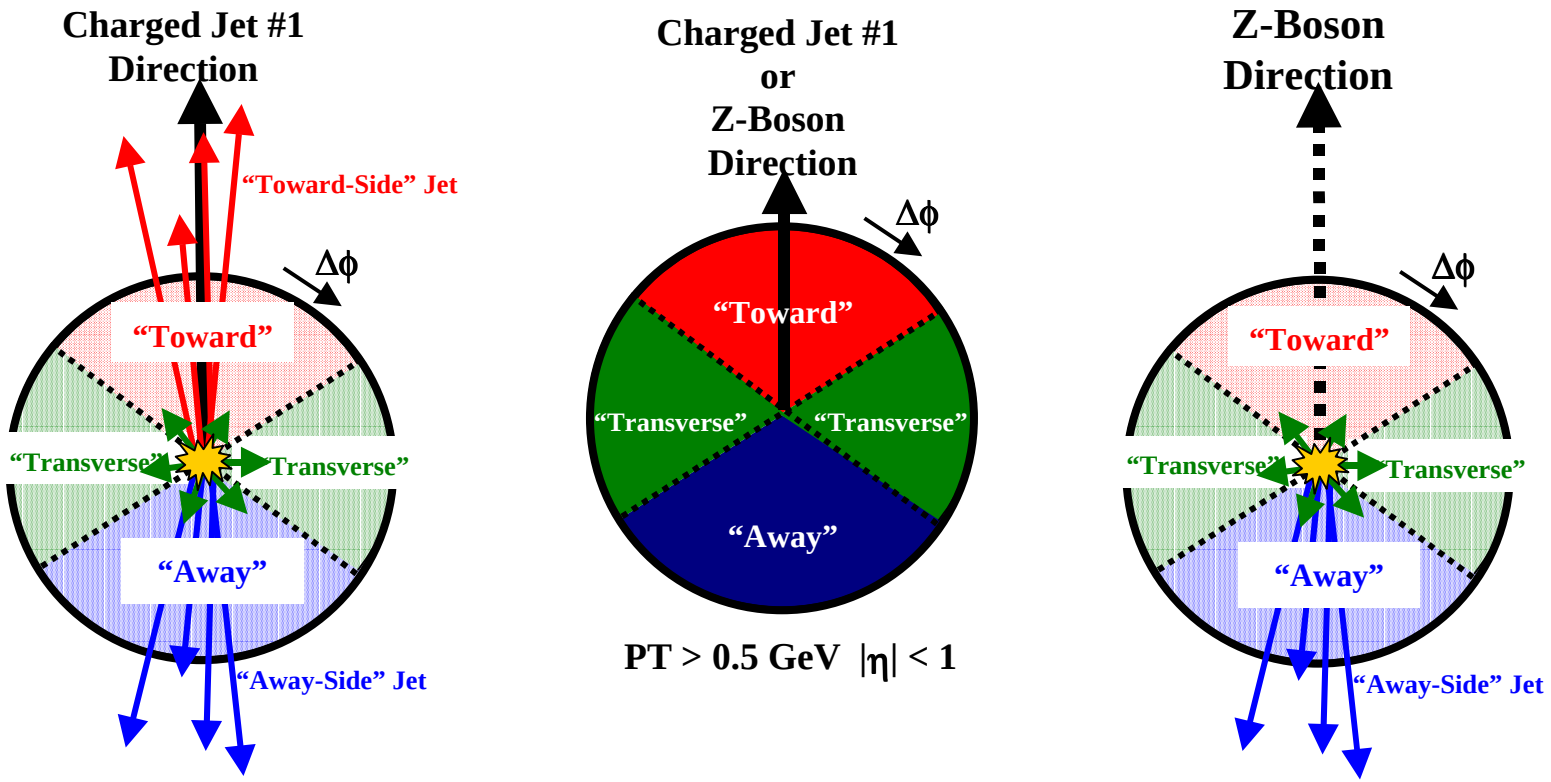
Make efficiency corrections

- **Require PT > 0.5 GeV, |η| < 1**
- **Make an 8% correction for the track finding efficiency**
- **Errors (statistical plus systematic) of around 5%**

Corrected theory

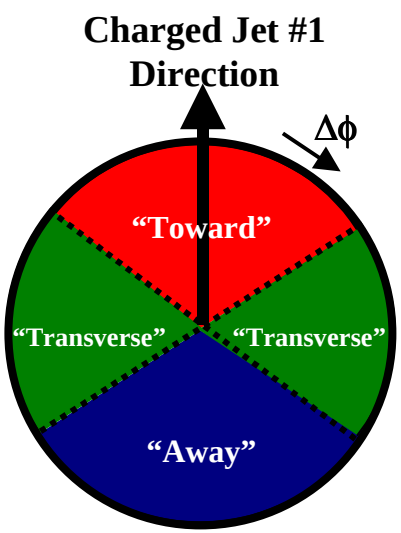
Small Corrections!

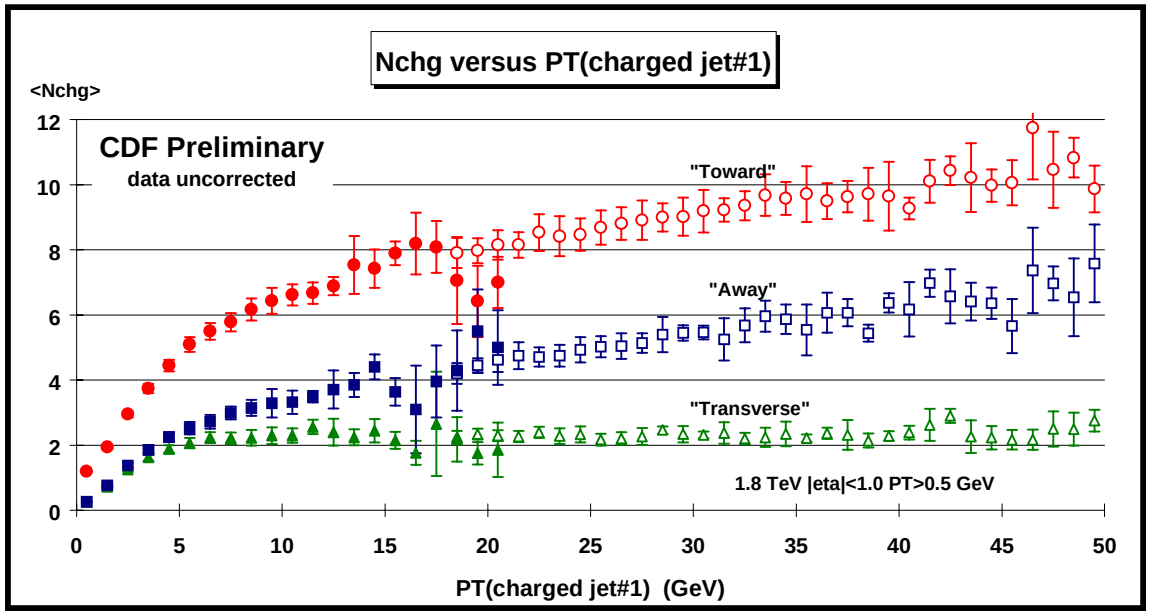
Charged Particle Δφ Correlations



- Look at charged particle correlations in the azimuthal angle Δφ.
- Define $|\Delta\phi| < 60^o$ as "Toward", $60^o < |\Delta\phi| < 120^o$ as "Transverse", and $|\Delta\phi| > 120^o$ as "Away".
- All three regions have the same size in η-φ space, $\Delta\eta \times \Delta\phi = 2 \times 120^o$.

DiJet: Charged Multiplicity versus PT(chgjet#1)

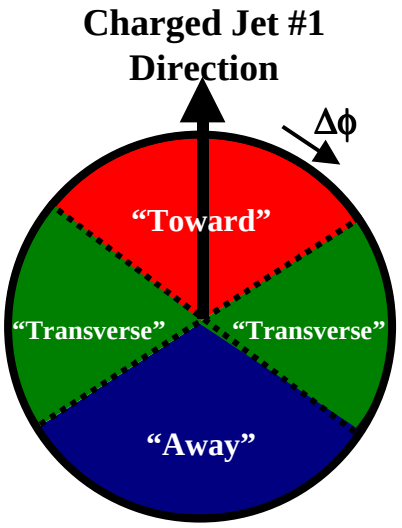


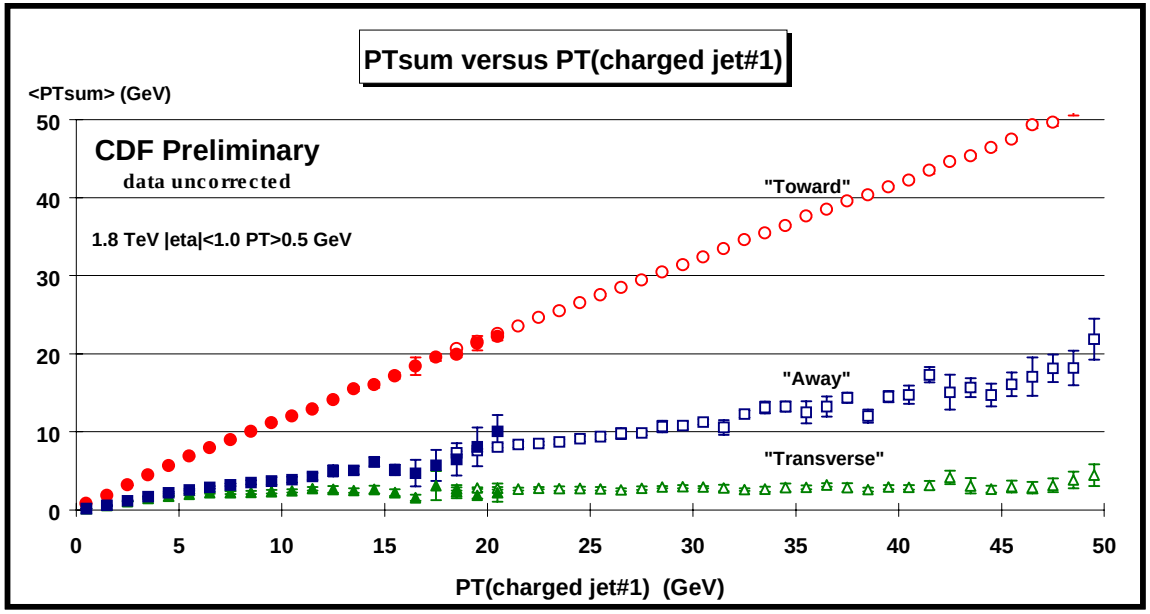


⇨ **Dijet data on the average number of "toward" ($|\Delta\phi|<60^o$), "transverse" ($60<|\Delta\phi|<120^o$), and "away" ($|\Delta\phi|>120^o$) charged particles ($P_T > 0.5$ GeV, $|\eta| < 1$, including jet#1) as a function of the transverse momentum of the leading charged particle jet. Each point corresponds to the <Nchg> in a 1 GeV bin. The solid (open) points are the Min-Bias (JET20) data. The errors on the (*uncorrected*) data include both statistical and correlated systematic uncertainties.**

Blessed on November 3, 1999

DiJet: Charged PTsum versus PT(chgjet#1)

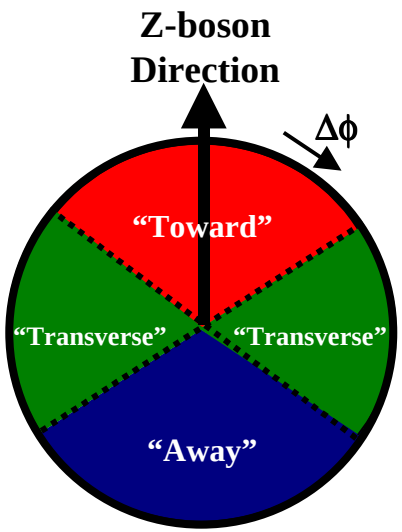


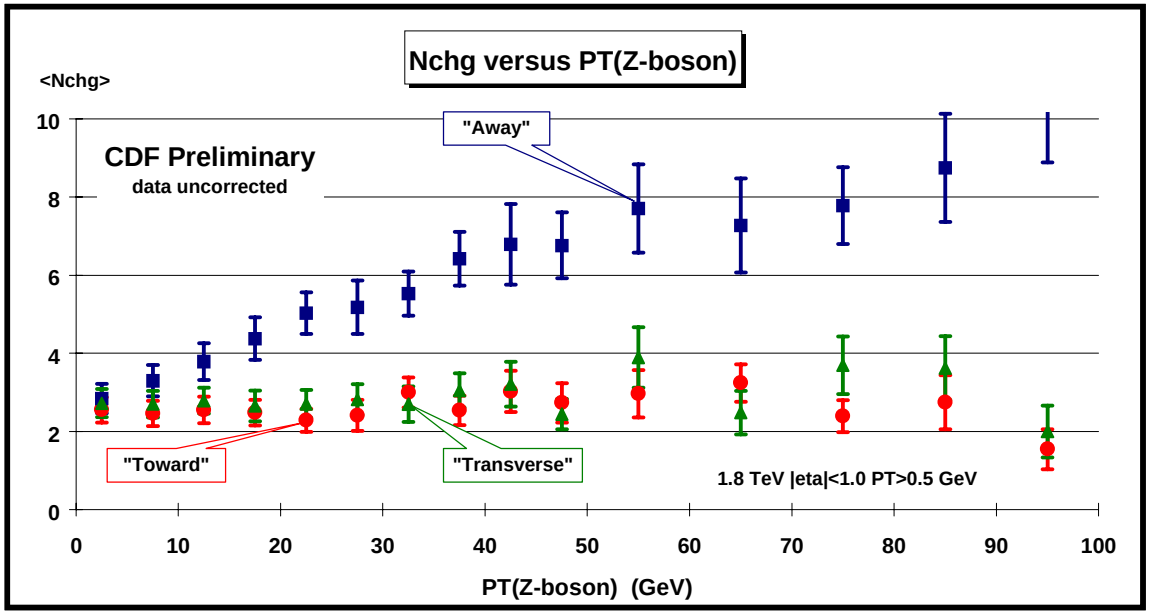


⇨ **Dijet data on the average scalar P_T sum of "toward" ($|\Delta\phi|<60^o$), "transverse" ($60<|\Delta\phi|<120^o$), and "away" ($|\Delta\phi|>120^o$) charged particles ($P_T > 0.5$ GeV, $|\eta| < 1$, including jet#1) as a function of the transverse momentum of the leading charged particle jet. Each point corresponds to the <PTsum> in a 1 GeV bin. The solid (open) points are the Min-Bias (JET20) data. The errors on the (*uncorrected*) data include both statistical and correlated systematic uncertainties.**

Blessed on November 3, 1999

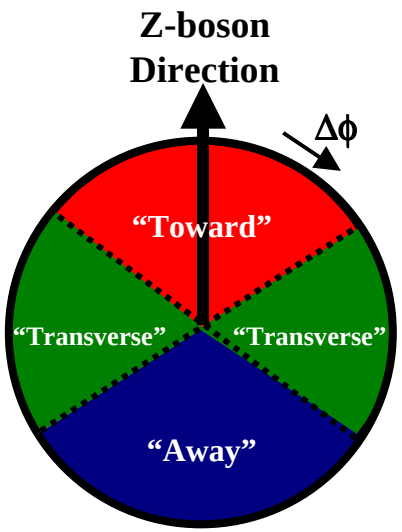
Z-boson: Charged Multiplicity versus PT(Z)

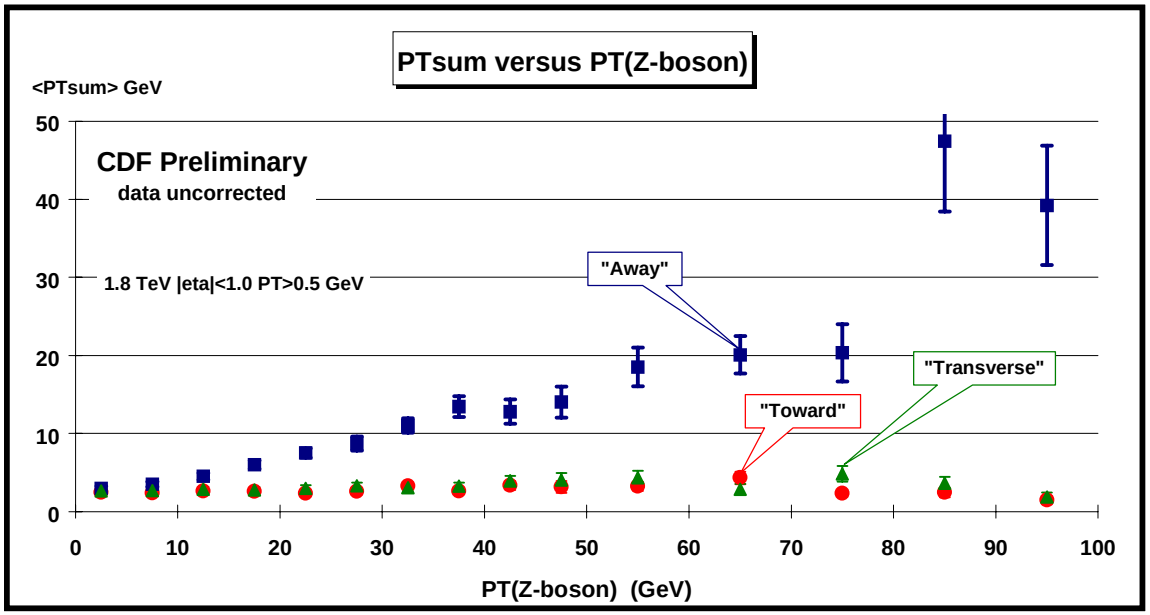




⇨ **Z-boson data on the average number of "toward" ($|\Delta\phi|<60^o$), "transverse" ($60<|\Delta\phi|<120^o$), and "away" ($|\Delta\phi|>120^o$) charged particles ($P_T > 0.5$ GeV, $|\eta| < 1$, excluding decay products of the Z-boson) as a function of the transverse momentum of the Z-boson. The errors on the (*uncorrected*) data include both statistical and correlated systematic uncertainties.**

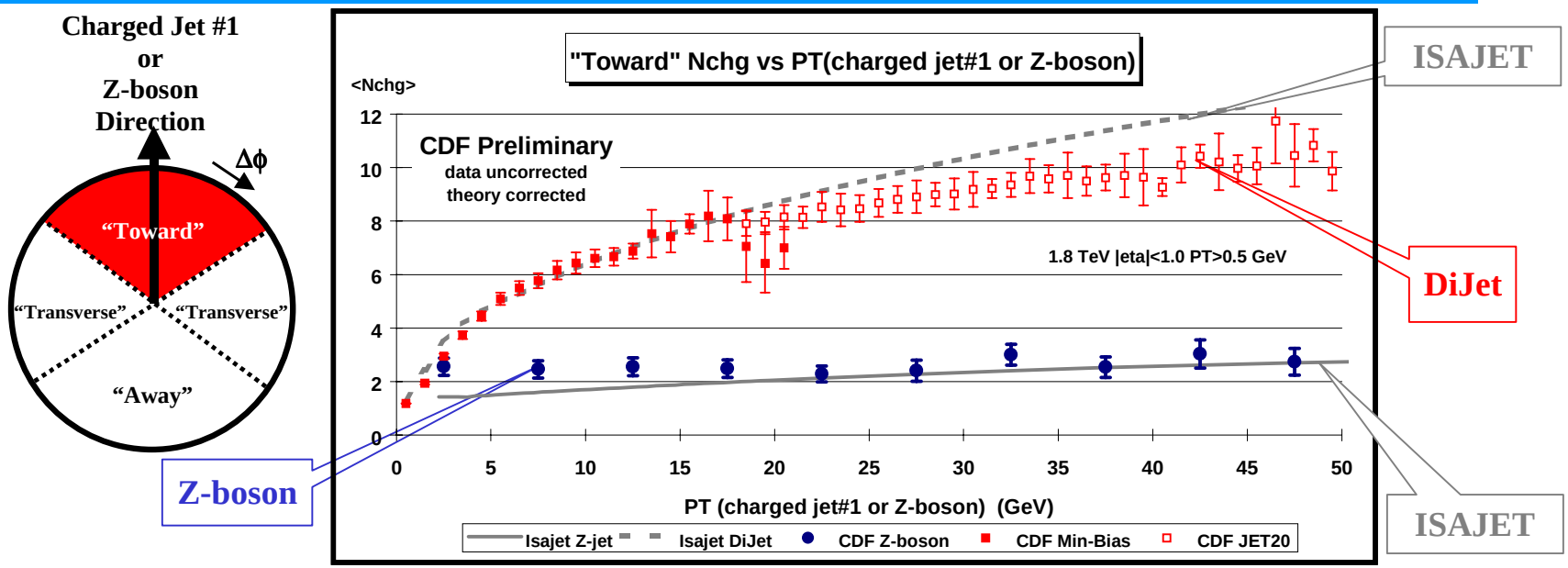
Z-boson: Charged PTsum versus PT(Z)





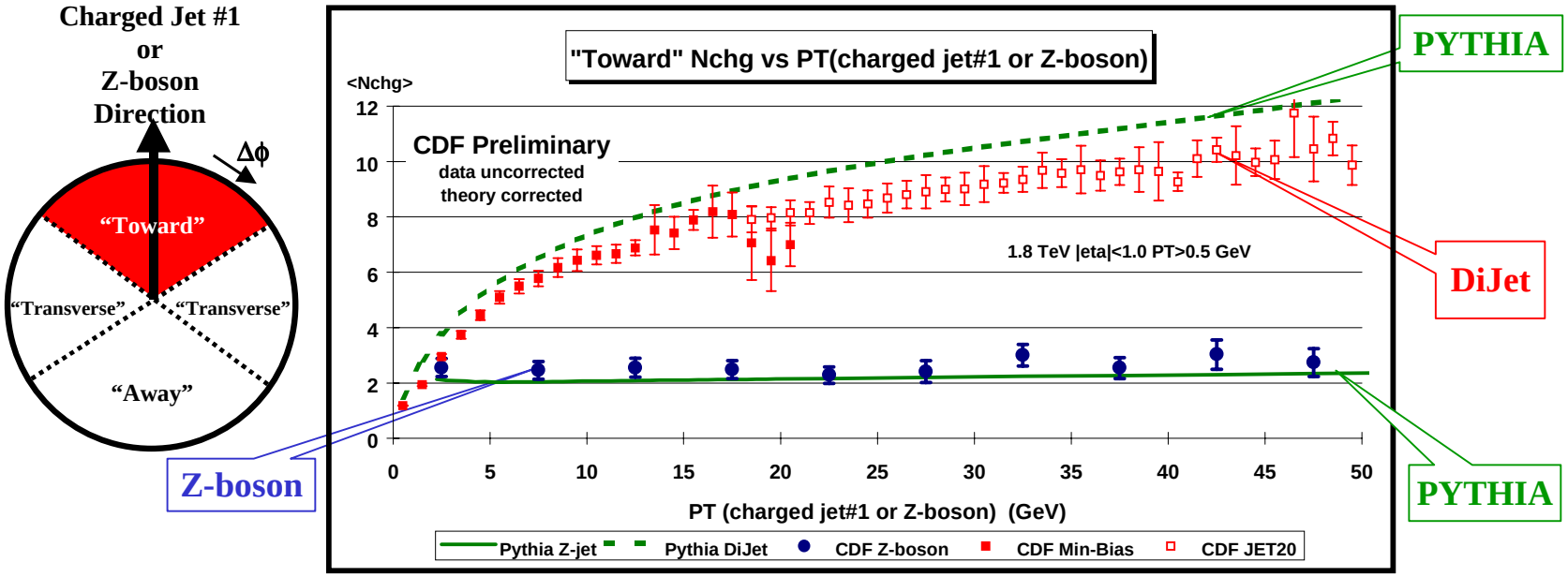
⇨ **Z-boson data on the average *scalar* P_T sum of "toward" ($|\Delta\phi|<60^o$), "transverse" ($60<|\Delta\phi|<120^o$), and "away" ($|\Delta\phi|>120^o$) charged particles ($P_T > 0.5$ GeV, $|\eta| < 1$, excluding decay products of the Z-boson) as a function of the transverse momentum of the Z-boson. The errors on the (*uncorrected*) data include both statistical and correlated systematic uncertainties.**

DiJet vs Z-Jet "Toward" Nchg



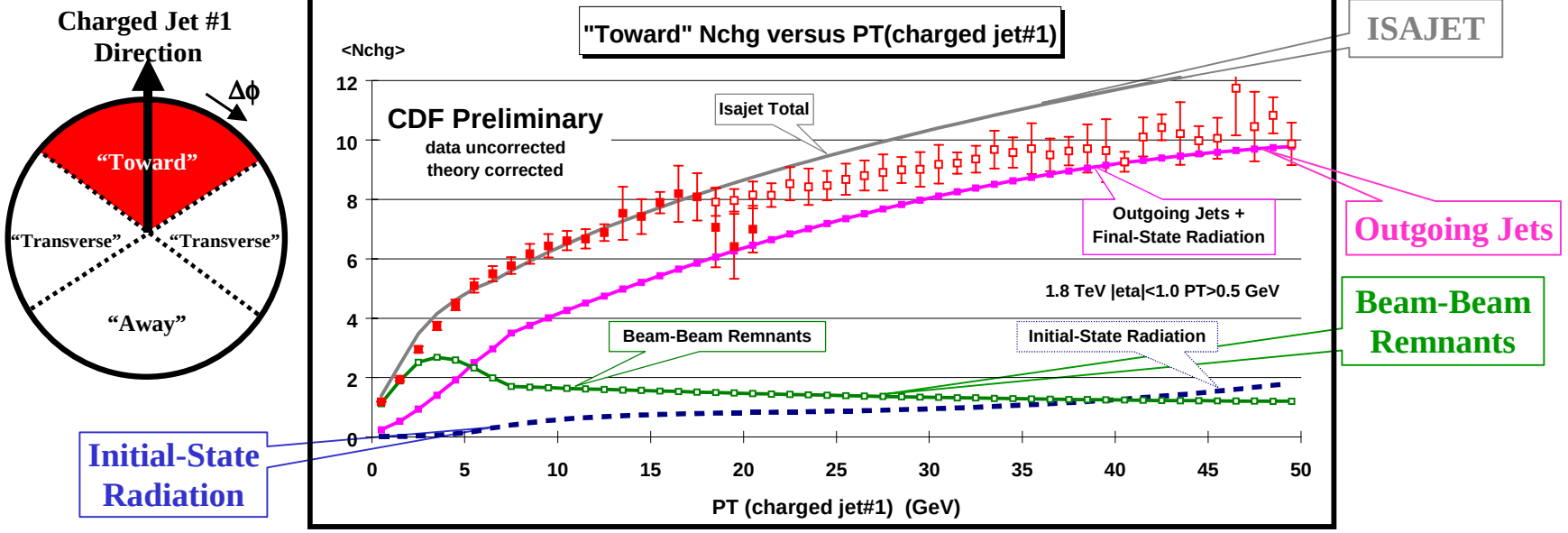
- Comparison of the dijet and the Z-boson data on the average number of charged particles (P_T > 0.5 GeV, |η| <1) for the "toward" region.
- The plot shows the QCD Monte-Carlo predictions of ISAJET 7.32 for dijet (dashed) and "Z-jet" (solid) production.

DiJet vs Z-Jet "Toward" Nchg



- Comparison of the dijet and the Z-boson data on the average number of charged particles (P_T > 0.5 GeV, |η| <1) for the "toward" region.
- The plot shows the QCD Monte-Carlo predictions of PYTHIA 6.115 for dijet (dashed) and "Z-jet" (solid) production.

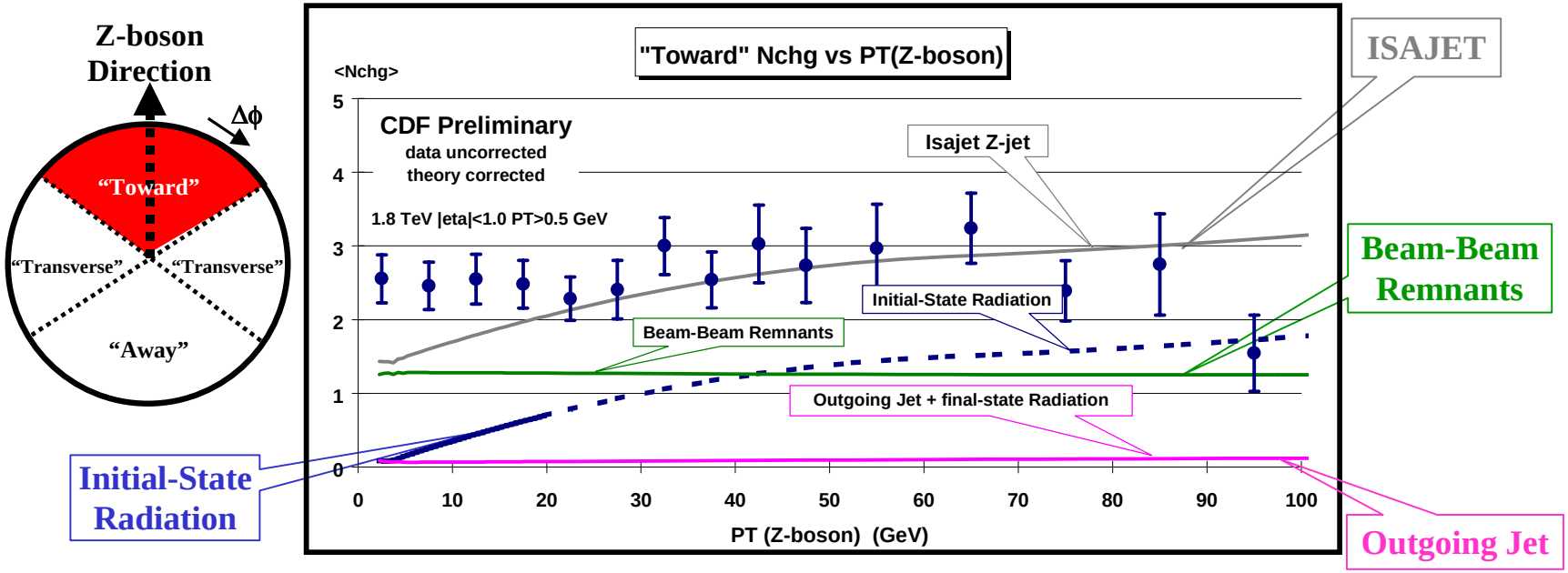
DiJet: "Toward" Nchg versus PT(chgjet#1)



- Plot shows the dijet "toward" <Nchg> vs P_T(chgjet#1) compared to the QCD "hard" scattering predictions of ISAJET 7.32.
- The predictions of ISAJET are divided into three categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants), charged particles that arise from initial-state radiation, and charged particles that result from the outgoing jets plus final-state radiation.

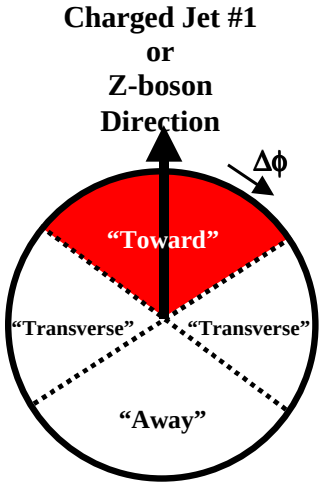
Blessed on February 25, 2000

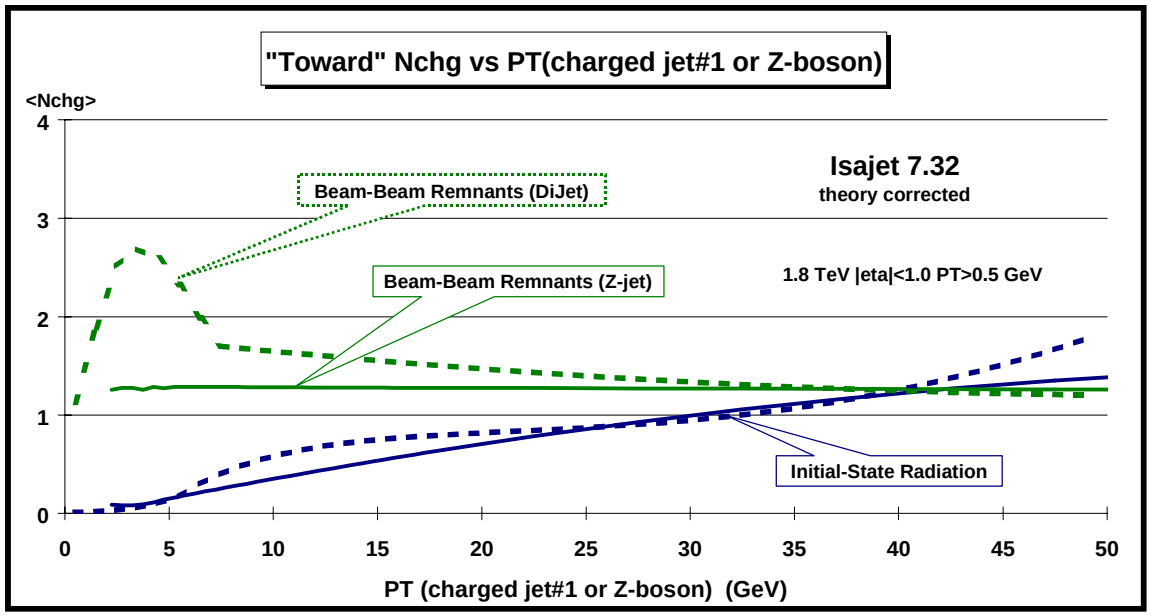
Z-boson: "Toward" Nchg versus PT(Z)



- Plot shows the Z-boson "toward" <Nchg> vs $P_T(Z)$ compared to the "Z+jet" QCD Monte-Carlo predictions of ISAJET 7.32.
- The predictions of ISAJET are divided into three categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants), charged particles that arise from initial-state radiation, and charged particles that result from the outgoing jet plus final-state radiation .

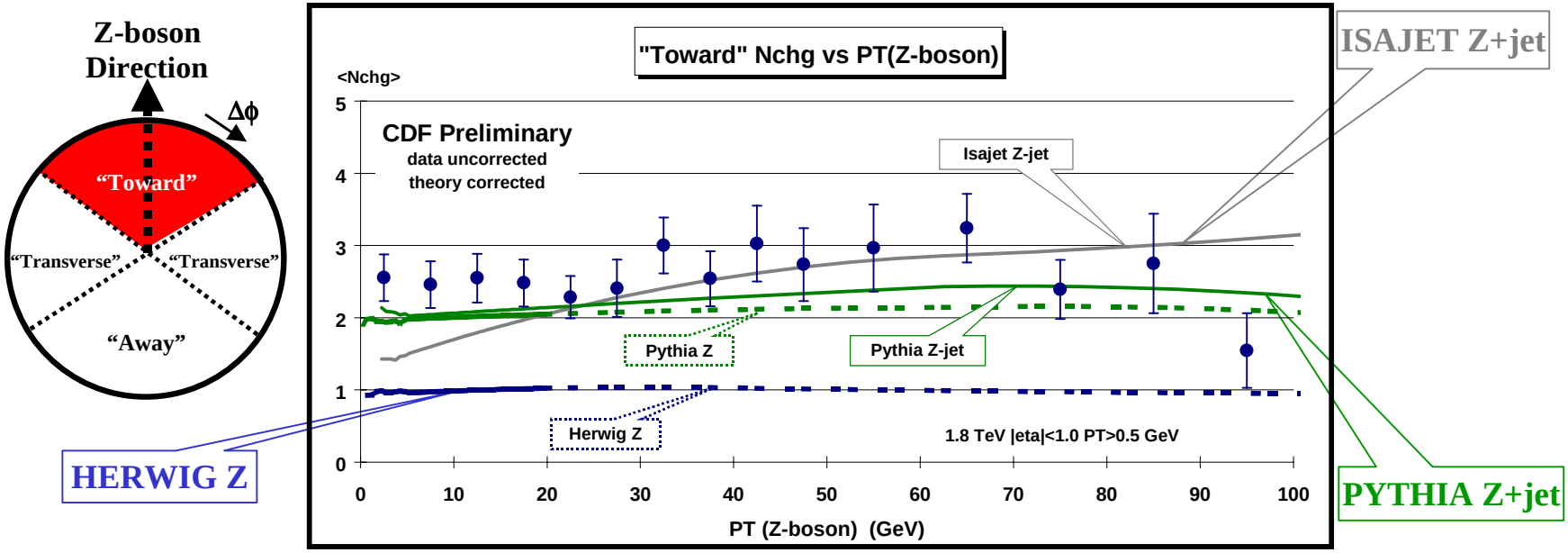
DiJet vs Z-Jet "Toward" Nchg





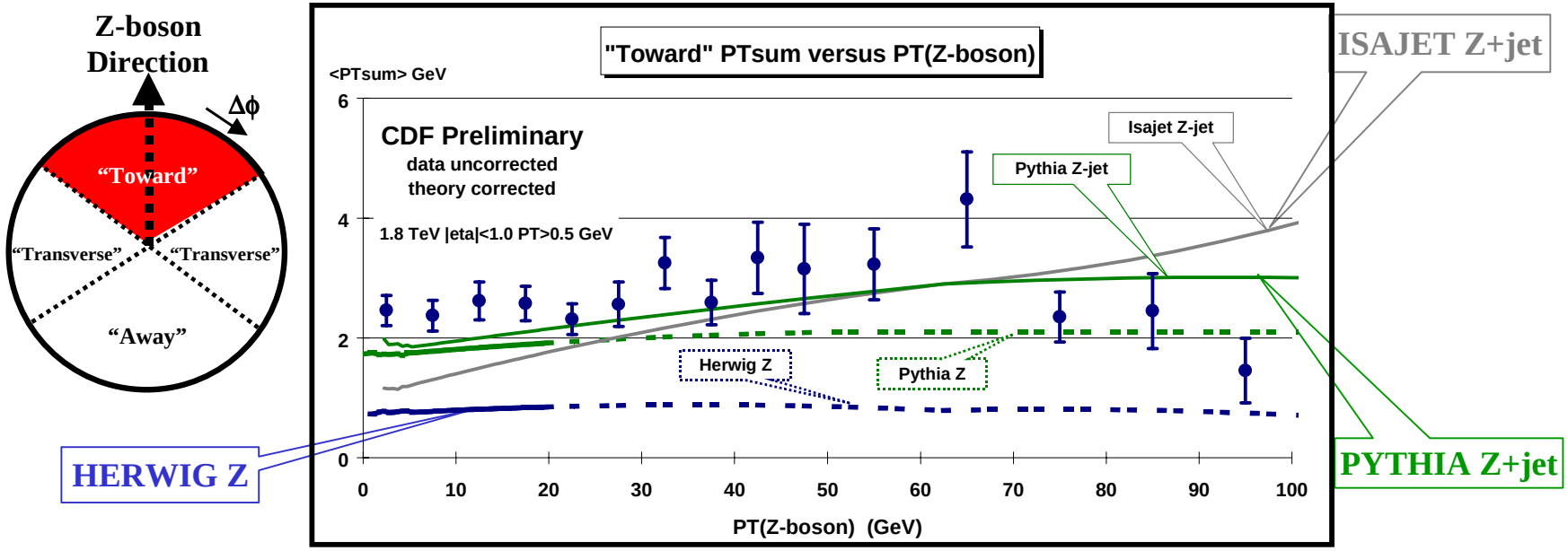
- Comparison of the QCD Monte-Carlo predictions of ISAJET 7.32 for the average number of charged particles ($P_T > 0.5$ GeV and $|\eta| < 1$) for the "toward" region for dijet (dashed) and "Z-jet" (solid) production.
- The plot shows the charged particles that arise from the break-up of the beam and target (beam-beam remnants) and the charged particles that arise from from initial-state radiation .

Z-boson: "Toward" Nchg versus PT(Z)



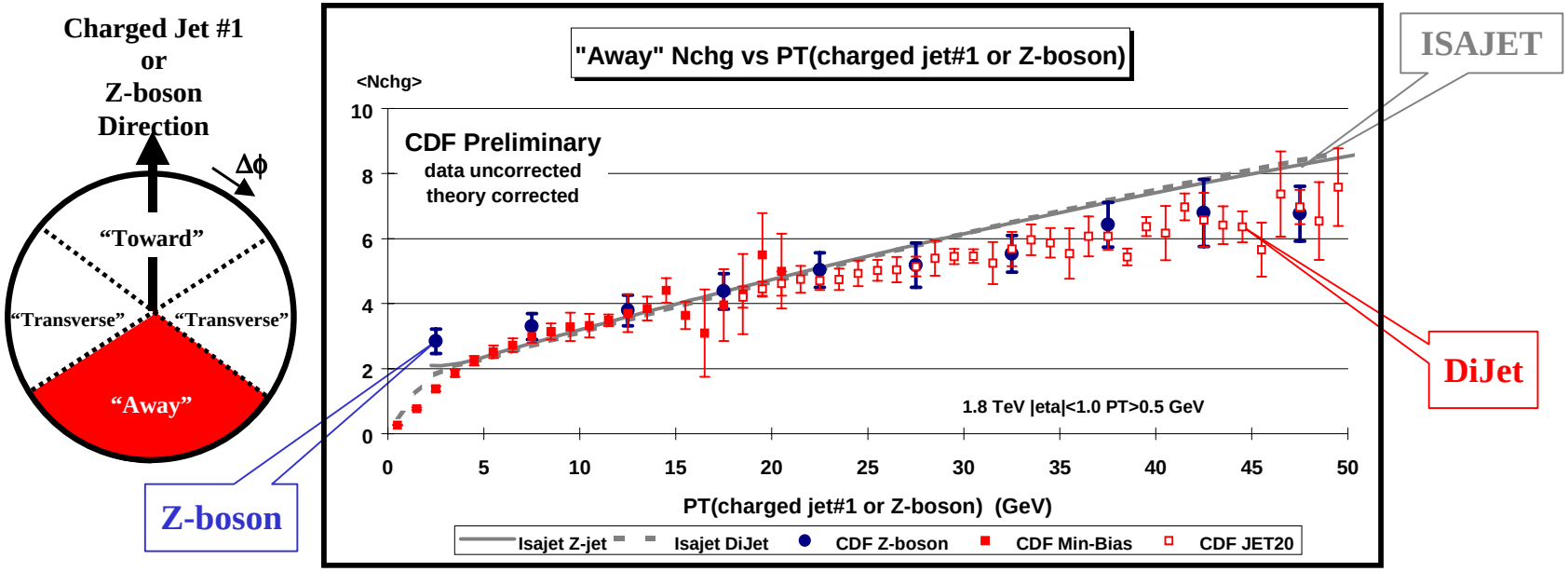
⇨ **Z-boson data on the average number of charged particles (P_T > 0.5 GeV and |η| < 1) as a function of P_T(Z) for the "toward" region compared with the QCD Monte-Carlo predictions of HERWIG 5.9 ("Z"), ISAJET 7.32 ("Z-jet"), and PYTHIA 6.115 ("Z", "Z-jet").**

Z-boson: "Toward" PTsum versus PT(Z)



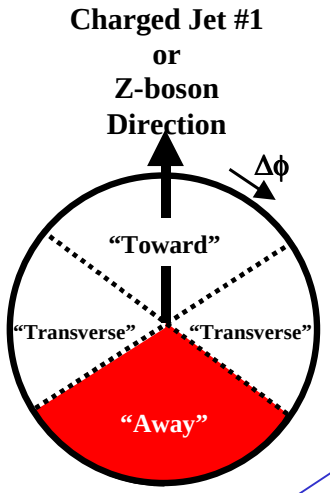
⇨ **Z-boson data on the average *scalar* P_T sum of charged particles ($P_T > 0.5$ GeV and $|\eta| < 1$) as a function of $P_T(Z)$ for the "toward" region compared with the QCD Monte-Carlo predictions of HERWIG 5.9 ("Z"), ISAJET 7.32 ("Z-jet"), and PYTHIA 6.115 ("Z", "Z-jet").**

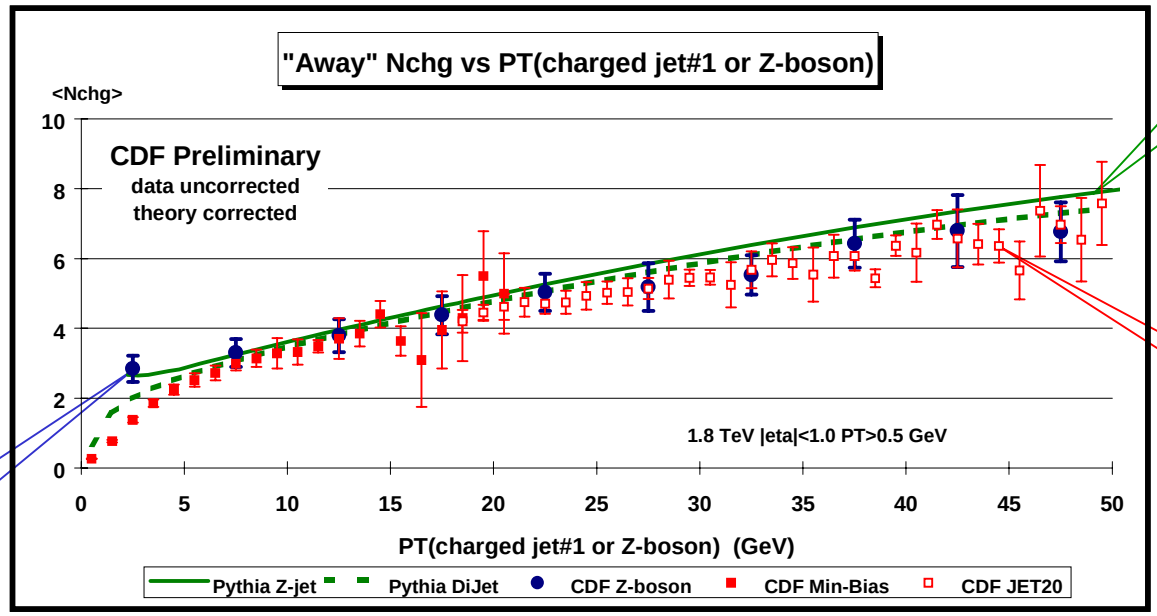
DiJet vs Z-Jet "Away" Nchg



- Comparison of the dijet and the Z-boson data on the average number of charged particles (P_T > 0.5 GeV, |η| <1) for the "away" region.
- The plot shows the QCD Monte-Carlo predictions of ISAJET 7.32 for dijet (dashed) and "Z-jet" (solid) production.

DiJet vs Z-Jet "Away" Nchg





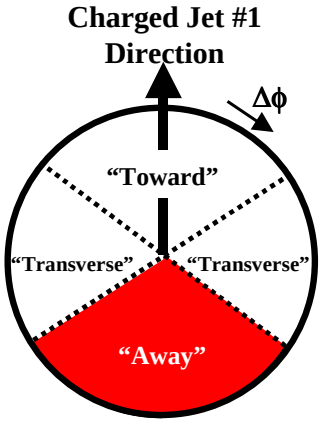
PYTHIA

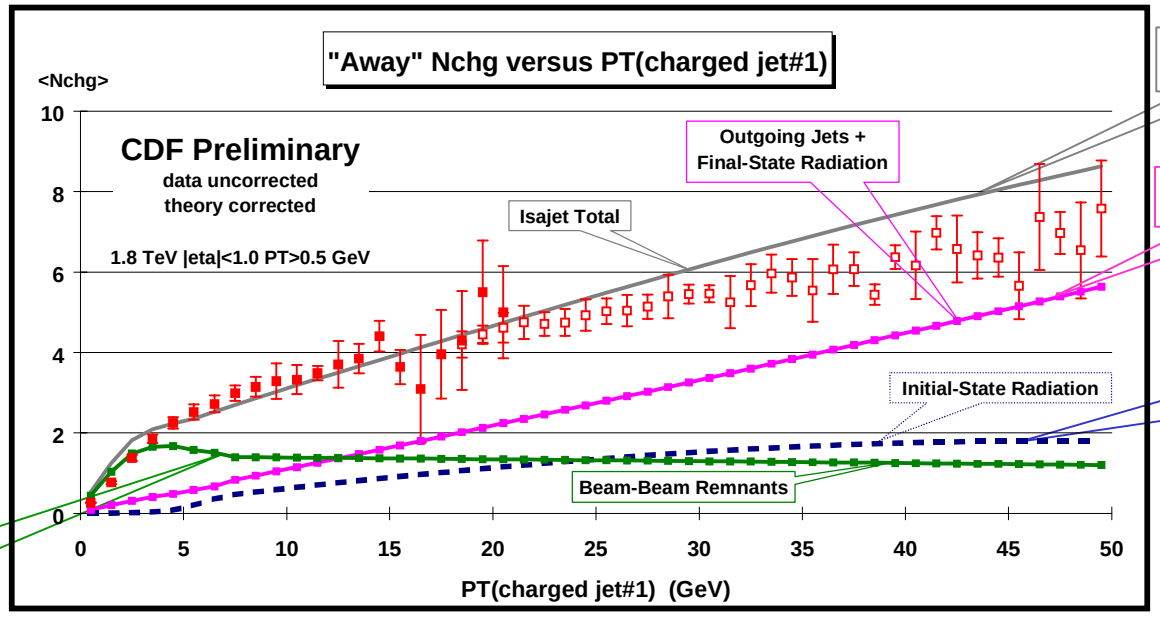
DiJet

Z-boson

- Comparison of the dijet and the Z-boson data on the average number of charged particles (P_T > 0.5 GeV, |η| <1) for the "away" region.
- The plot shows the QCD Monte-Carlo predictions of PYTHIA 6.115 for dijet (dashed) and "Z-jet" (solid) production.

DiJet: "Away" Nchg versus PT(chgjet#1)





- Plot shows the dijet "away" <Nchg> vs P_T(chgjet#1) compared to the QCD "hard" scattering predictions of ISAJET 7.32.
- The predictions of ISAJET are divided into three categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants), charged particles that arise from initial-state radiation, and charged particles that result from the outgoing jets plus final-state radiation .

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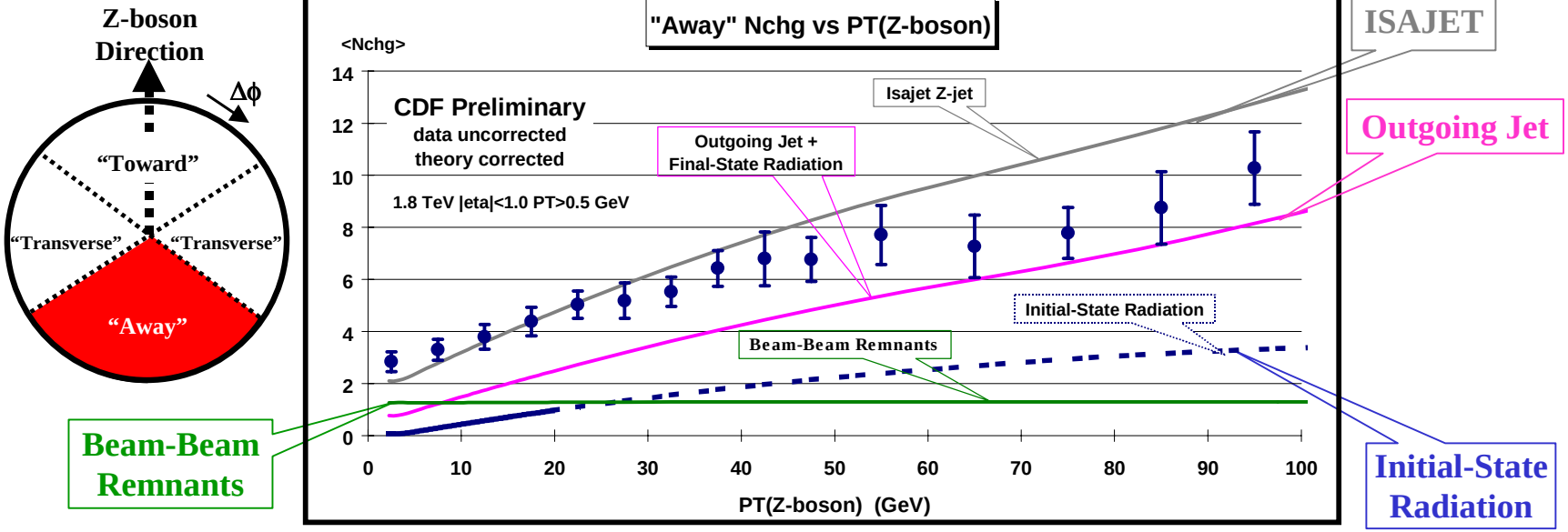
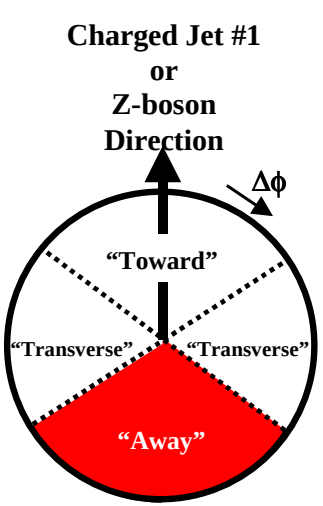
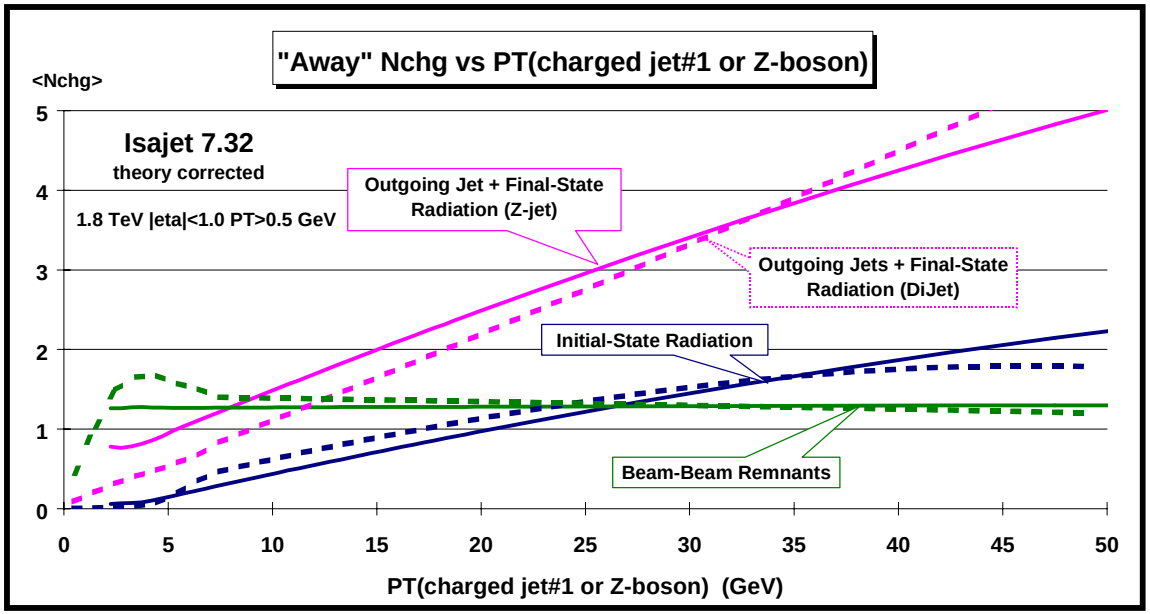
Z-boson: "Away" Nchg versus PT(Z)



- Plot shows the Z-boson "away" <Nchg> vs $P_T(Z)$ compared to the "Z+jet" QCD Monte-Carlo predictions of ISAJET 7.32.
- The predictions of ISAJET are divided into three categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants), charged particles that arise from initial-state radiation, and charged particles that result from the outgoing jets plus final-state radiation.

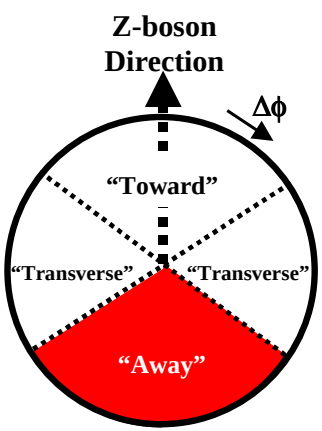
DiJet vs Z-Jet "Away" Nchg

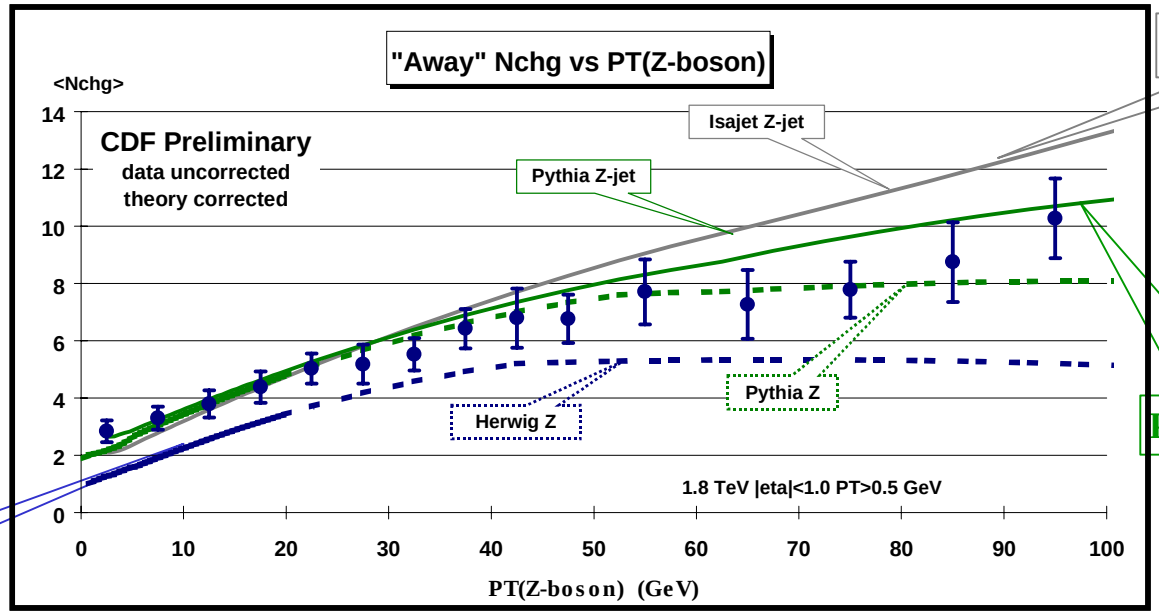




- Comparison of the QCD Monte-Carlo predictions of ISAJET 7.32 for the average number of charged particles ($P_T > 0.5$ GeV and $|\eta| < 1$) for the "away" region for dijet (dashed) and "Z-jet" (solid) production.
- The plot shows the charged particles that arise from the break-up of the beam and target (beam-beam remnants), and the charged particles that arise from from initial-state radiation, and the charge particles that come from the outgoing jet plus final-state radiation.

Z-boson: "Away" Nchg versus PT(Z)





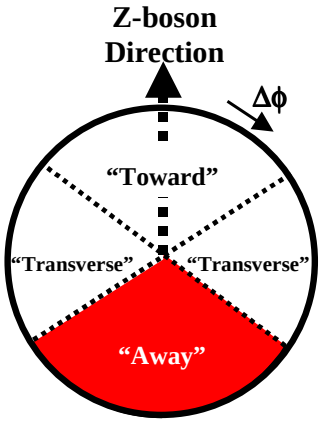
ISAJET Z+jet

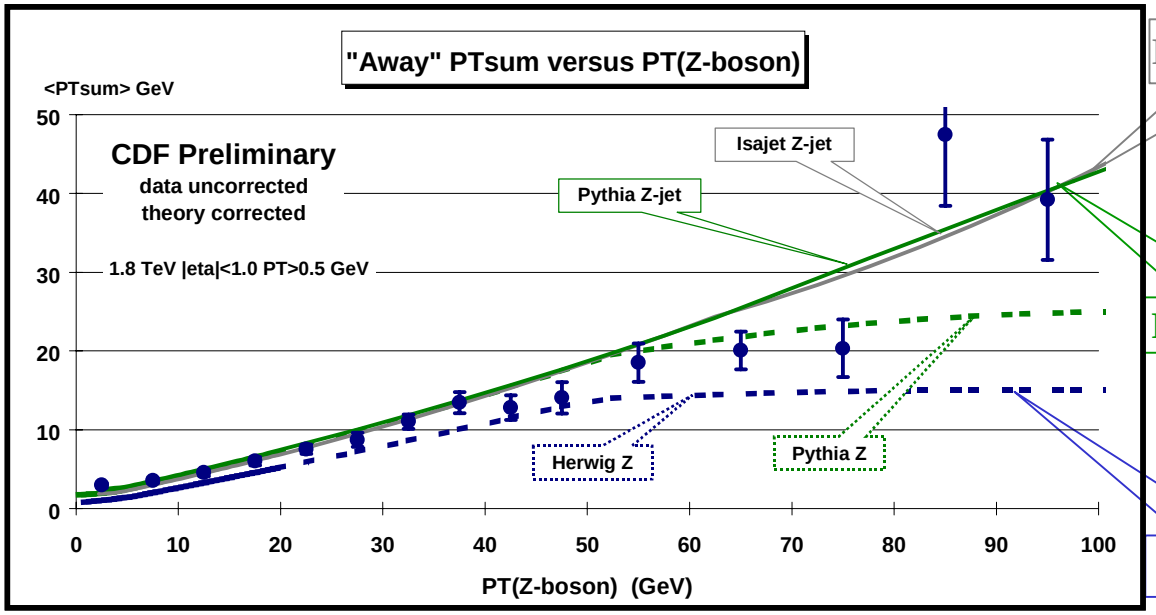
PYTHIA Z+jet

HERWIG Z

⇨ **Z-boson data on the average number of charged particles (P_T > 0.5 GeV and $|\eta|$ < 1) as a function of P_T(Z) for the "away" region compared with the QCD Monte-Carlo predictions of HERWIG 5.9 ("Z"), ISAJET 7.32 ("Z-jet"), and PYTHIA 6.115 ("Z", "Z-jet").**

Z-boson: "Away" PTsum versus PT(Z)





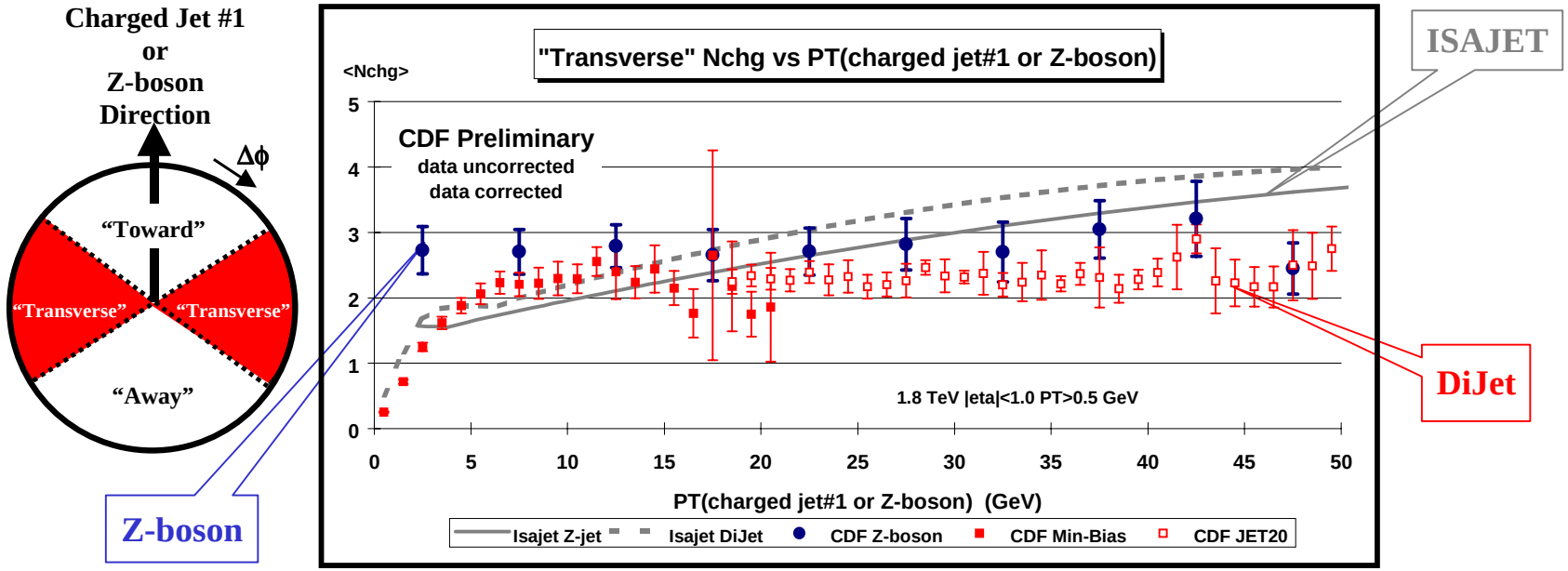
ISAJET Z+jet

PYTHIA Z+jet

HERWIG Z

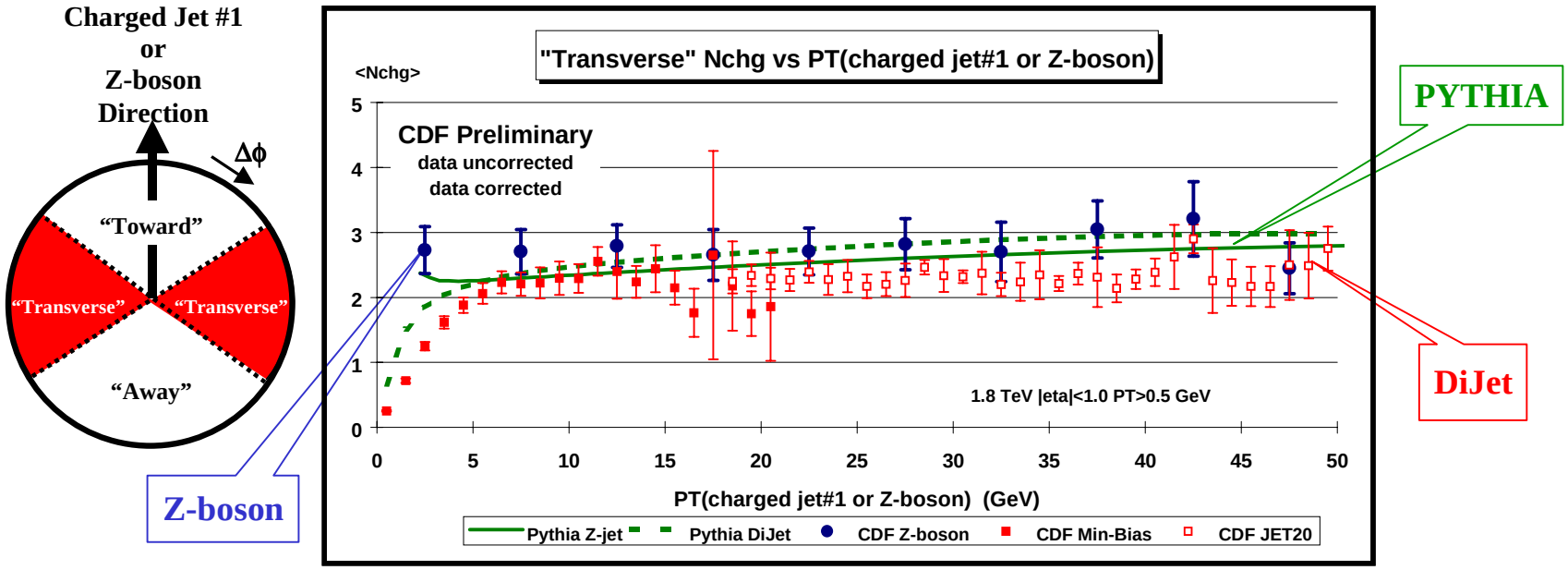
⇨ **Z-boson data on the average *scalar* P_T sum of charged particles (P_T > 0.5 GeV and |η| < 1) as a function of P_T(Z) for the "away" region compared with the QCD Monte-Carlo predictions of HERWIG 5.9 ("Z"), ISAJET 7.32 ("Z-jet"), and PYTHIA 6.115 ("Z", "Z-jet").**

DiJet vs Z-Jet "Transverse" Nchg



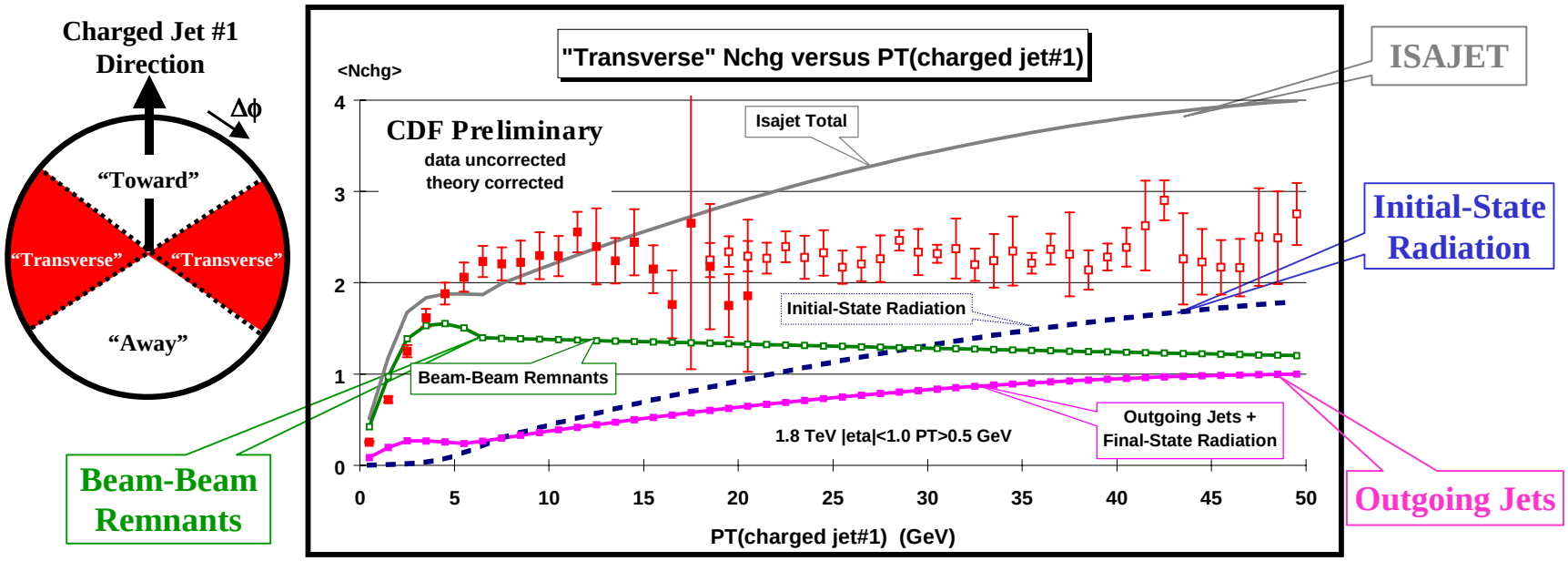
- Comparison of the dijet and the Z-boson data on the average number of charged particles (P_T > 0.5 GeV, |η| <1) for the "transverse" region.
- The plot shows the QCD Monte-Carlo predictions of ISAJET 7.32 for dijet (dashed) and "Z-jet" (solid) production.

DiJet vs Z-Jet "Transverse" Nchg



- Comparison of the dijet and the Z-boson data on the average number of charged particles (P_T > 0.5 GeV, |η| <1) for the "transverse" region.
- The plot shows the QCD Monte-Carlo predictions of PYTHIA 6.115 for dijet (dashed) and "Z-jet" (solid) production.

DiJet: "Transverse" Nchg versus PT(chgjet#1)



- Plot shows the dijet "transverse" <Nchg> vs P_T(chgjet#1) compared to the QCD "hard" scattering predictions of ISAJET 7.32.
- The predictions of ISAJET are divided into three categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants), charged particles that arise from initial-state radiation, and charged particles that result from the outgoing jets plus final-state radiation.

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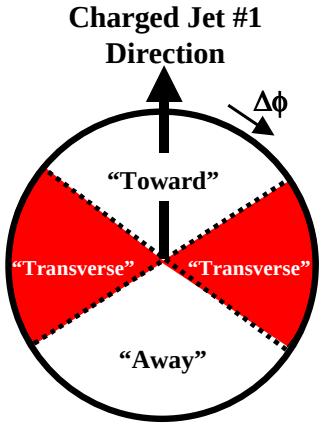
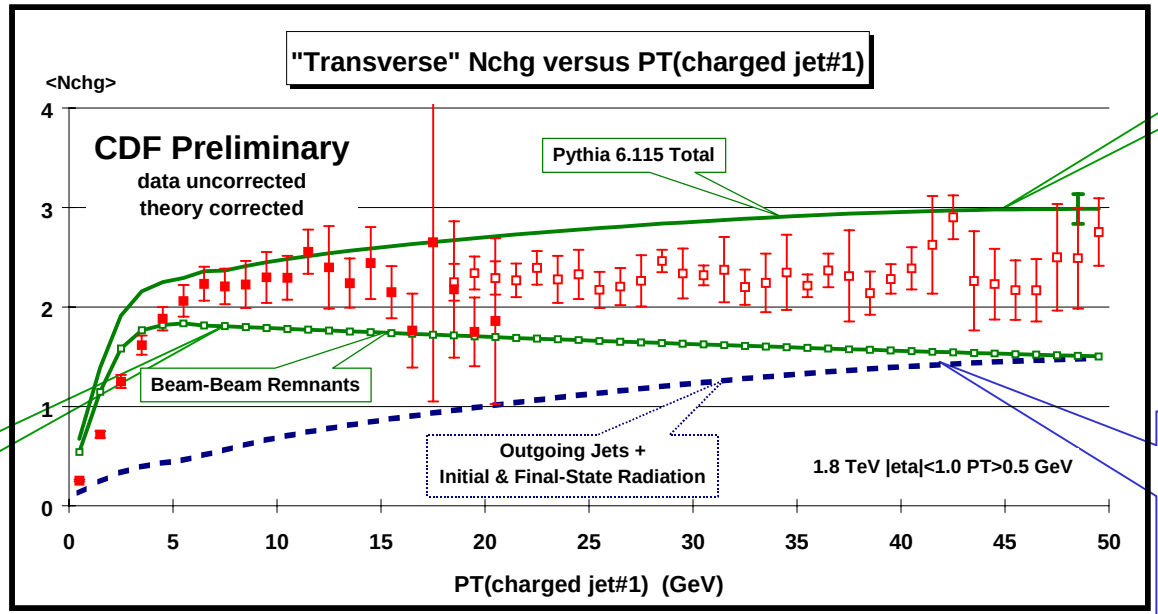
DiJet: "Transverse" Nchg versus PT(chgjet#1)





PYTHIA

Beam-Beam Remnants

Outgoing Jets plus Initial & Final-State Radiation

- Plot shows the dijet "transverse" <Nchg> vs P_T(chgjet#1) compared to the QCD "hard" scattering predictions of PYTHIA 6.115.
- The predictions of PYTHIA are divided into two categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants); and charged particles that arise from the outgoing jet plus initial and final-state radiation (hard scattering component).

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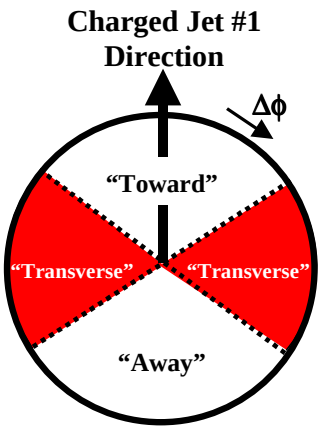
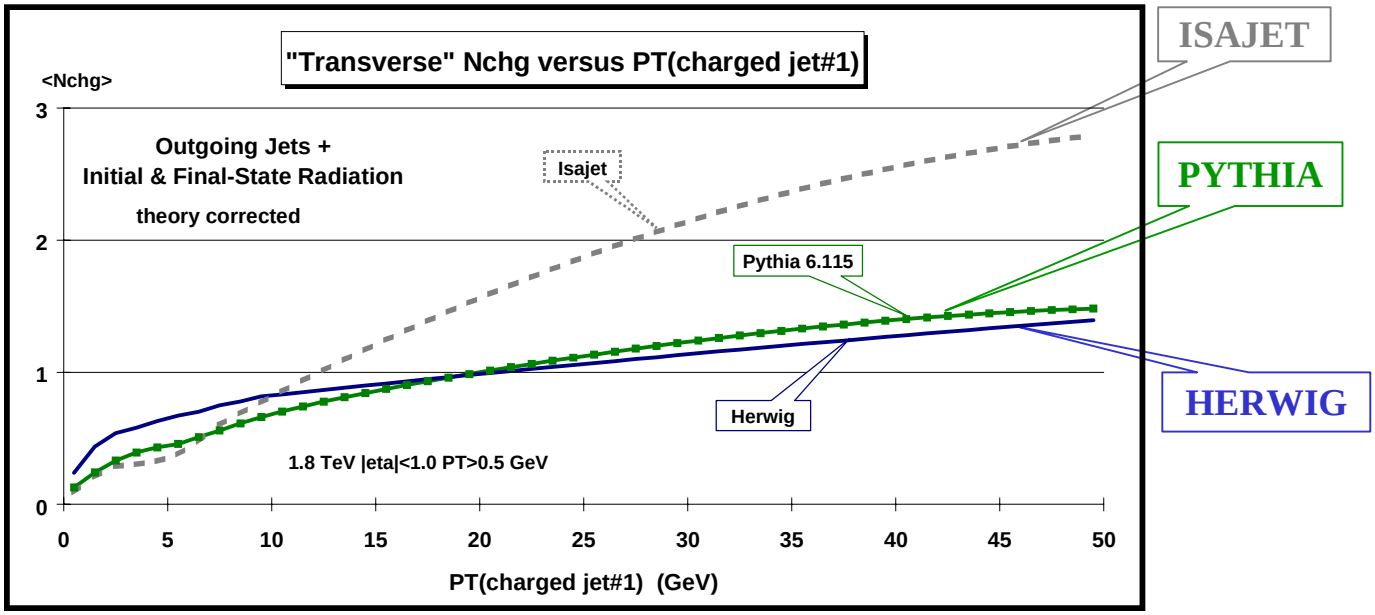
DiJet: "Transverse" Nchg versus PT(chgjet#1)

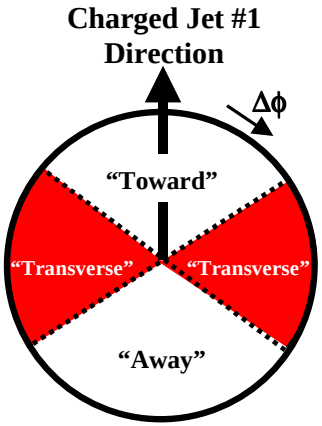


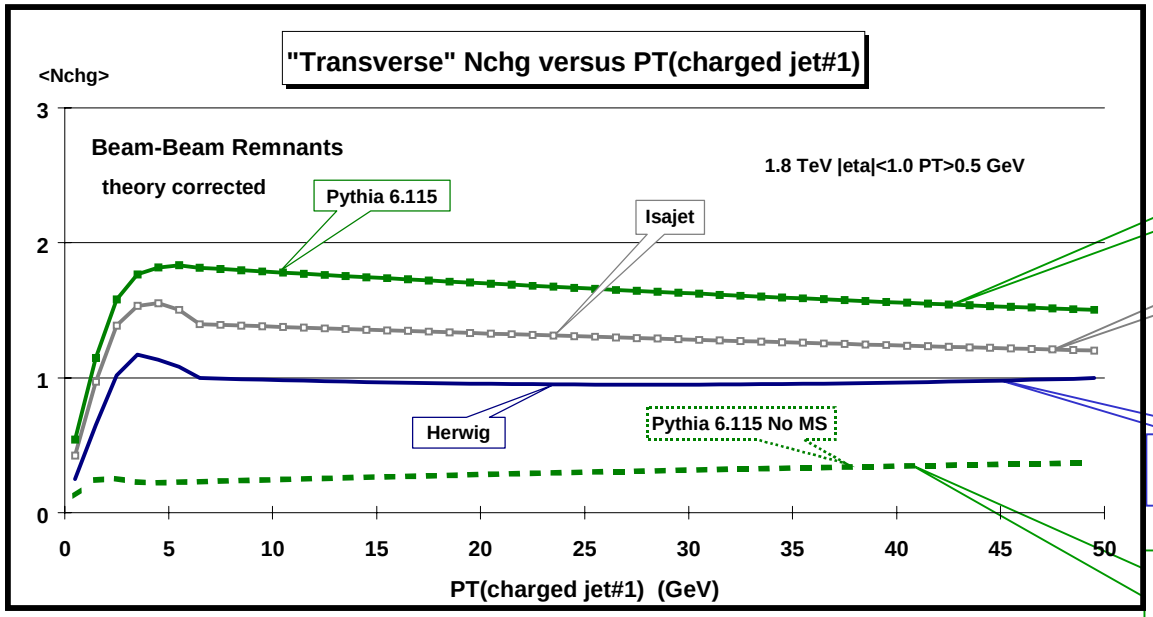


- QCD "hard" scattering predictions of **HERWIG 5.9**, **ISAJET 7.32**, and **PYTHIA 6.115**.
- Plot shows the dijet **"transverse" <Nchg> vs P_T(chgjet#1)** arising from the outgoing jets plus initial and finial-state radiation (**hard scattering component**).

Blessed on February 25, 2000

DiJet: "Transverse" Nchg versus PT(chgjet#1)





PYTHIA

ISAJET

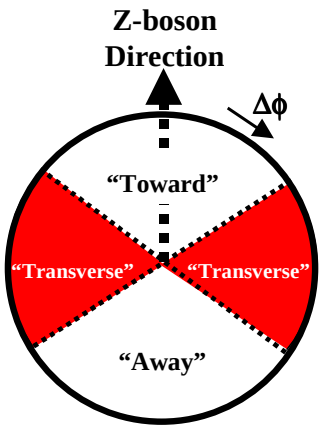
HERWIG

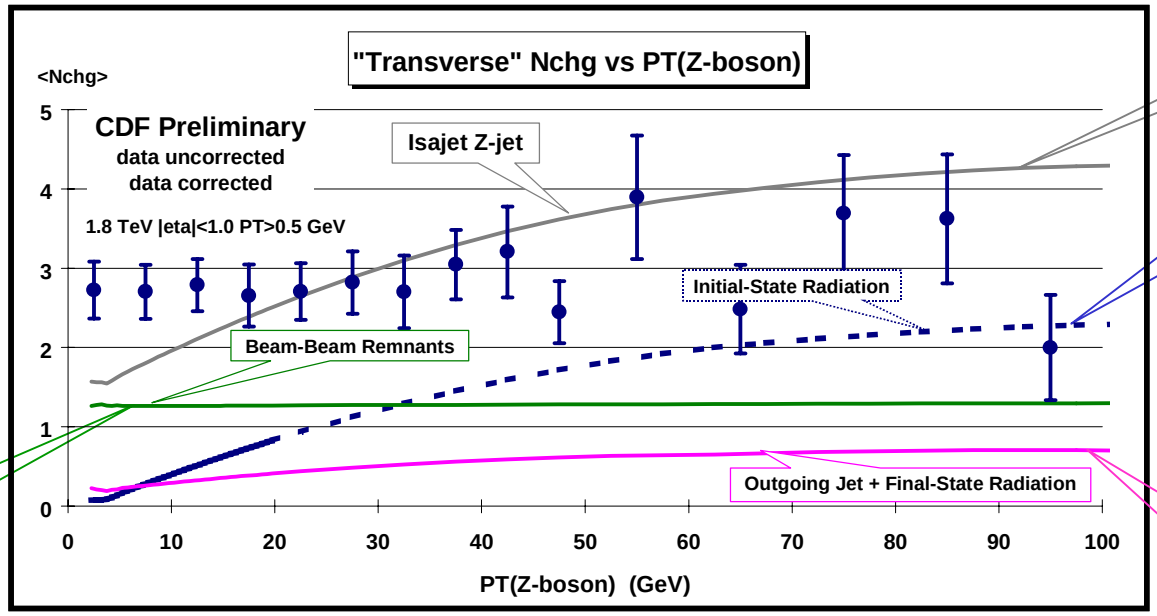
PYTHIA with No Multiple Parton Scattering

- QCD "hard" scattering predictions of HERWIG 5.9, ISAJET 7.32, and PYTHIA 6.115.
- Plot shows the dijet "transverse" <Nchg> vs P_T(chgjet#1) arising from the beam-beam remnants. For Pythia the beam-beam remnants include contributions from multiple parton scattering.

Blessed on February 25, 2000

Z-boson: "Transverse" Nchg versus PT(Z)





ISAJET

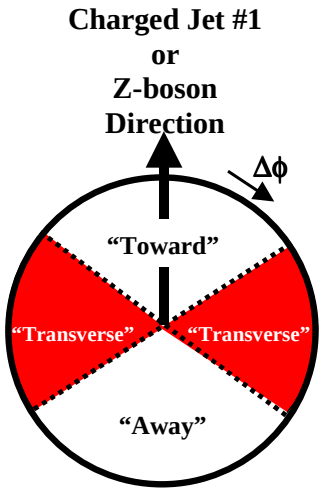
Initial-State Radiation

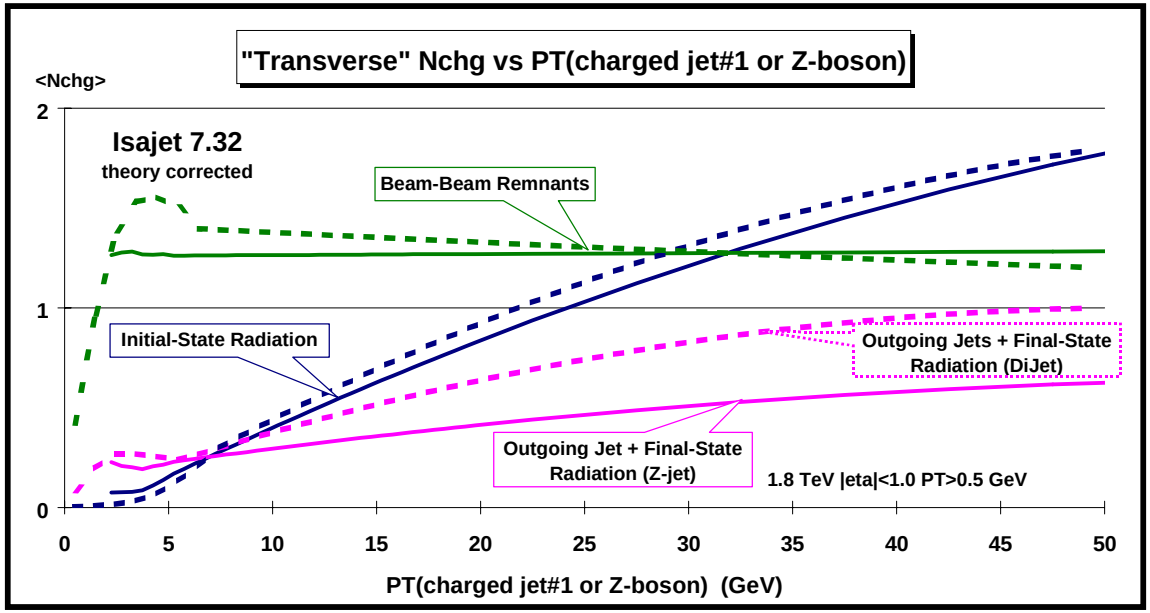
Beam-Beam Remnants

Outgoing Jet

- Plot shows the Z-boson "transverse" <Nchg> vs $P_T(Z)$ compared to the "Z+jet" QCD Monte-Carlo predictions of ISAJET 7.32.
- The predictions of ISAJET are divided into three categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants), charged particles that arise from initial-state radiation, and charged particles that result from the outgoing jets plus final-state radiation.

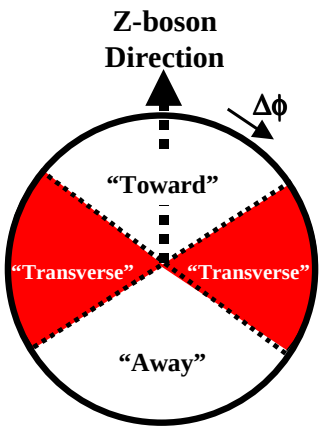
DiJet vs Z-Jet "Transverse" Nchg

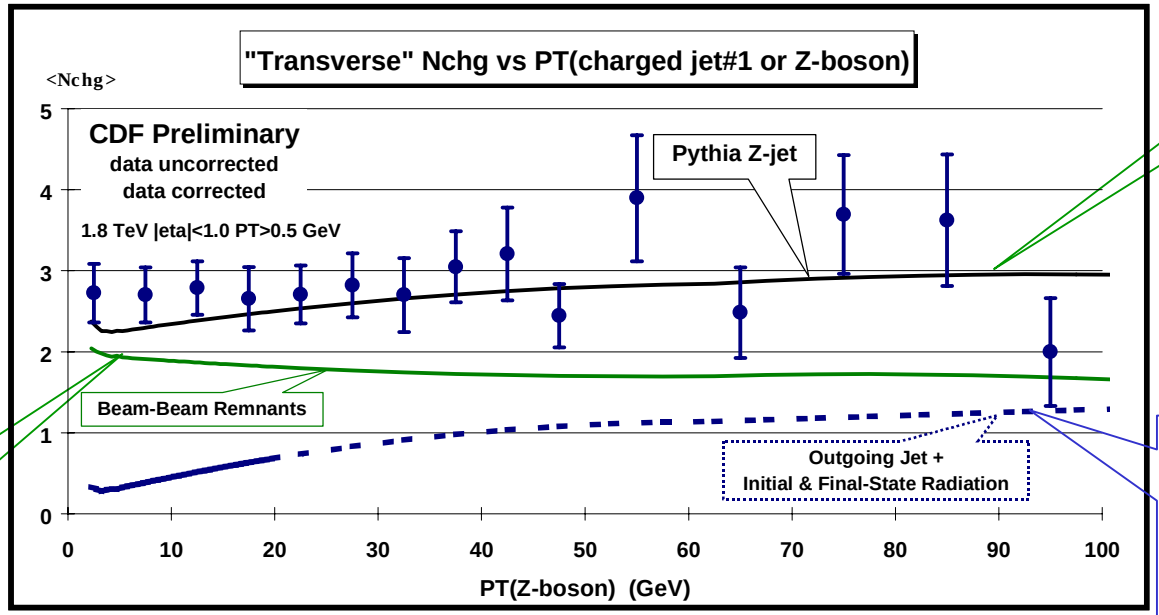




- **Comparison of the QCD Monte-Carlo predictions of ISAJET 7.32 for the average number of charged particles (P_T > 0.5 GeV and |η| < 1) for the "transverse" region for dijet (dashed) and "Z-jet" (solid) production.**
- **The plot shows the charged particles that arise from the break-up of the beam and target (beam-beam remnants), and the charged particles that arise from from initial-state radiation, and charged particles that result from the outgoing jets plus final-state radiation .**

Z-boson: "Transverse" Nchg versus PT(Z)





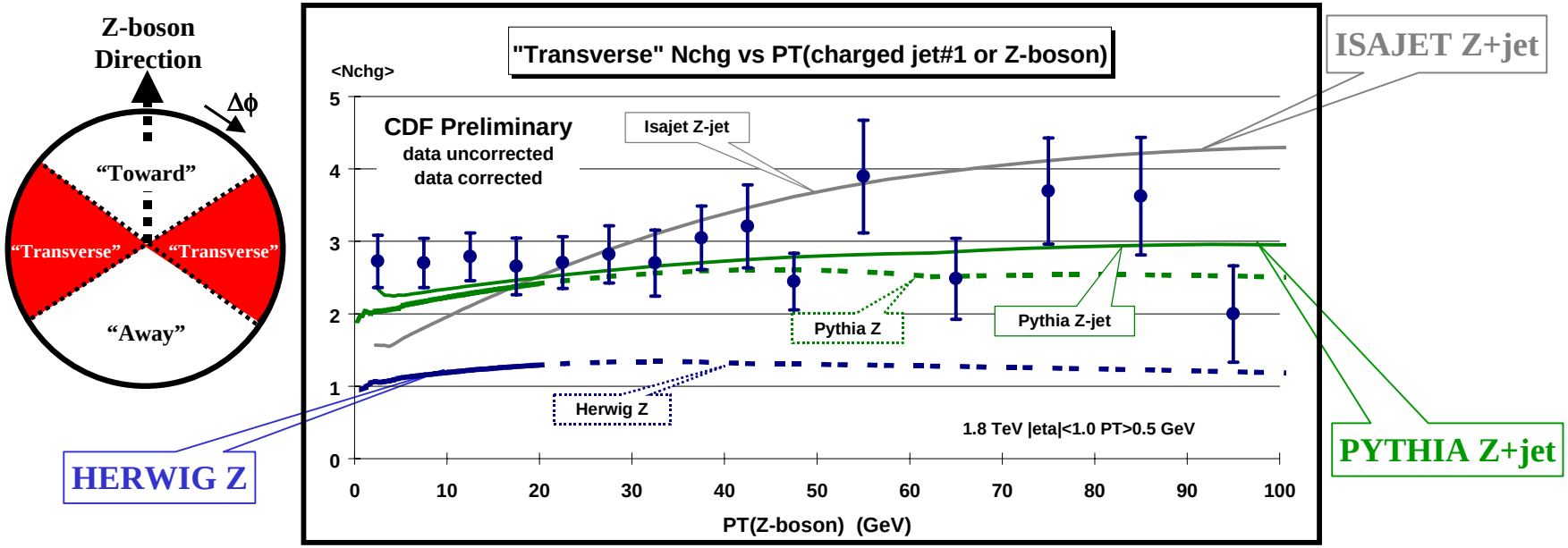
PYTHIA

Beam-Beam Remnants

Outgoing Jet plus Initial & Final-State Radiation

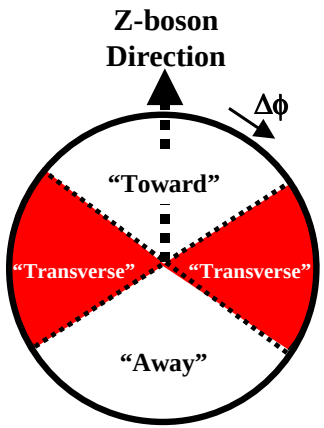
- Plot shows the Z-boson "transverse" <Nchg> vs $P_T(Z)$ compared to the "Z+jet" QCD Monte-Carlo predictions of PYTHIA 6.115.
- The predictions of PYTHIA are divided into two categories: charged particles that arise from the break-up of the beam and target (beam-beam remnants); and charged particles that arise from the outgoing jet plus initial and final-state radiation (hard scattering component).

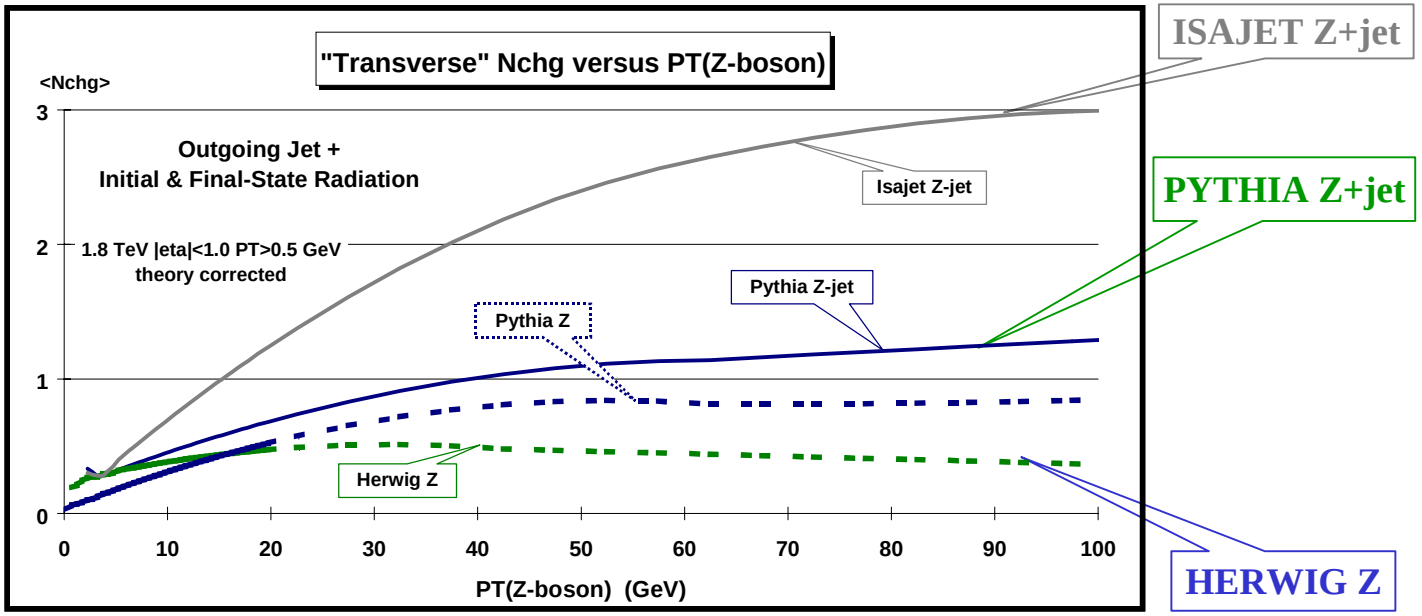
Z-boson: "Transverse" Nchg versus PT(Z)



⇨ **Z-boson data on the average number of charged particles (P_T > 0.5 GeV and |η| < 1) as a function of P_T(Z) for the "transverse" region compared with the QCD Monte-Carlo predictions of HERWIG 5.9 ("Z"), ISAJET 7.32 ("Z-jet"), and PYTHIA 6.115 ("Z", "Z-jet").**

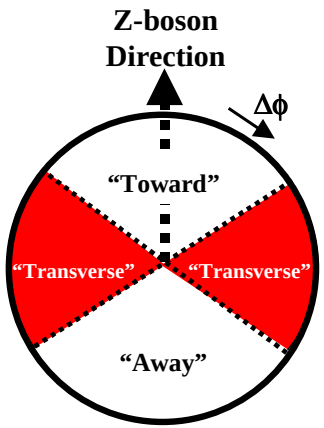
Z-boson: "Transverse" Nchg versus PT(Z)

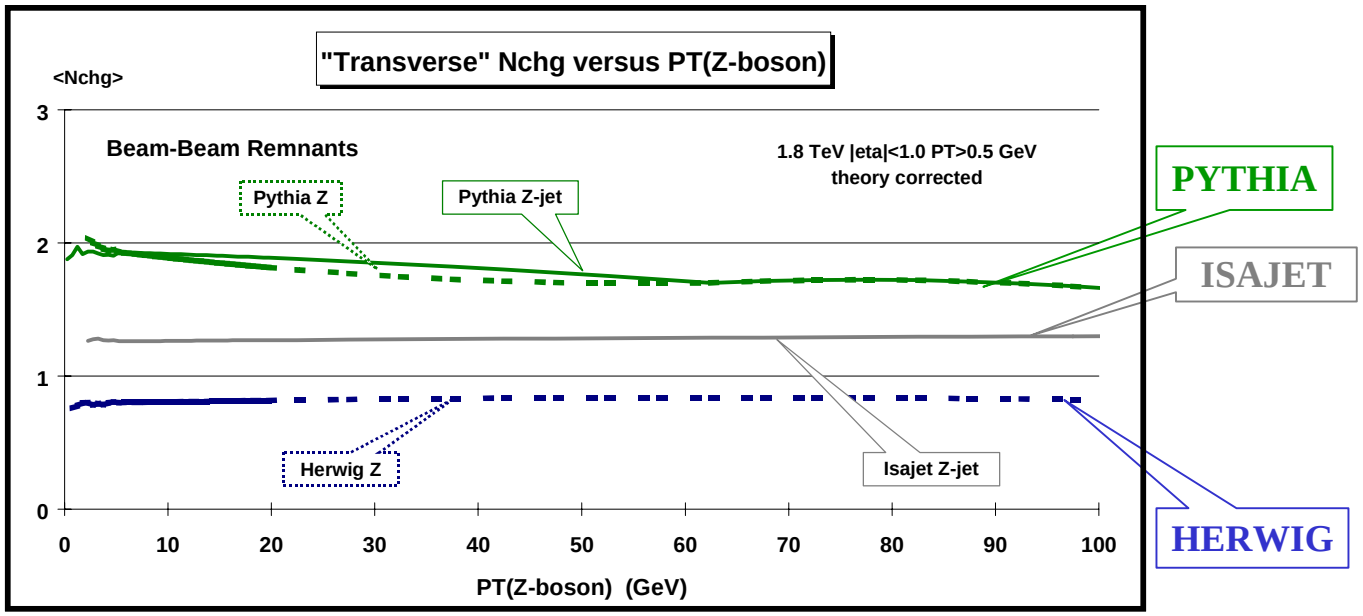




- **QCD Monte-Carlo predictions of HERWIG 5.9 ("Z"), ISAJET 7.32 ("Z-jet"), and PYTHIA 6.115 ("Z", "Z-jet").**
- **Plot shows the Z-boson "transverse" <Nchg> vs $P_T(Z)$ arising from the outgoing jets plus initial and finial-state radiation (hard scattering component).**

Z-boson: "Transverse" Nchg versus PT(Z)





- QCD Monte-Carlo predictions of **HERWIG 5.9 ("Z")**, **ISAJET 7.32 ("Z-jet")**, and **PYTHIA 6.115 ("Z", "Z-jet")**.
- Plot shows the Z-boson **"transverse" <Nchg> vs $P_T(Z)$** arising from the **beam-beam remnants**. For PYTHIA the beam-beam remnants include contributions from **multiple parton scattering**.